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University of California, Berkeley
Jet Propulsion Laboratory
Northwestern University

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13. ABSTRACT *(Maximum 200 words)*

The report Summarizes the objectives and principal results of the research carried out over the entire term of the MURI project. It includes a list of publications and a list of scientific personnel involved.

14. SUBJECT TERMS

fuel cells, electrodeposited catalysts, methanol crossover

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October 12, 2001

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Dear Ms. Oakley:

Enclosed please the original and two copies of the Final Progress Report for 2001 from our research group. Please reference the information below:

ARO Proposal Number: 33907-CH-MUR

Contract or Grant Number: DAAHO4-95-1-0094

Title of Proposal: Mobile Electric Power: High Performance PEM Fuel Cells

Name of Institution: University of Minnesota

If we should send more, please advise me. You may reach me by phone, fax, or e-mail as per below.

Sincerely,

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Sincerely,

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33907CH-MUR

Enclosure 4

REPORT DOCUMENTATION PAGE (SF298)
(Continuation Sheet)

Mobile Electric Power: High Performance PEM Fuel Cells

FINAL PROGRESS REPORT

Professor William H. Smyrl
Professor Edward L. Cussler
Professor David A. Shores
Professor Kent R. Mann
Adjunct Professor Boone B. Owens
Professor John S. Newman
Professor Du Shriver

October 12, 2001

Contract/Grant Number: DAAHO4-95-1-0094

University of Minnesota

I. Program Objectives

- Identify and characterize new polymer membrane materials with reduced methanol permeation (Objective 1).
- Identify and characterize novel electrode structures incorporating new porous carbon materials and alternative catalysts (Objective 2).
- Establish an exploratory fuel cell testing facility to evaluate novel components in a complete PEMFC environment (Objective 3).

II. Summary of the Most Important Results

MURI accomplishments

Objective 1: (A) A basis has been developed for evaluation and screening of commercial and new polymer membrane electrolytes. The proton conductivity and inverse methanol permeability are the two characteristics that determine the selectivity basis.

(B) A new composite polymer membrane has been discovered for direct methanol fuel cells. The better membrane is a composite of polyvinylalcohol and mordenite, a natural zeolite. It is 20 times more selective for protons vs methanol than Nafion - the current industry standard.

(C) Modified polyphosphazenes are a new class of rigid polymer electrolyte that have been synthesized for enhanced conductivity with low rates of methanol transport.

Objective 2. (A) Very low catalyst (Pt-Ru) loading levels of 0.03 mg/cm^2 have shown good performance for methanol oxidation.

(B) Reactive sputtering of Pt-Ru in oxygen atmospheres has been shown to eliminate conditioning time, and there is no need for ionomer in the catalyst layer.

(C) Miniature fuel cells have been fabricated for methanol/air and for hydrogen/air utilizing techniques adapted from microeletronic and MEMS micromachining procedures. The cells approach the performance of large state-of-the-art cells when scaled for size. The cells are made with high reproducibility and highly precise features. The volume of an individual cell is 12 mm^3.

III. Electrodeposited Pt-Ru catalysts with loadings of 0.25 mg/cm^2 perform well in both miniature cells and in large cells. Comparison with state-of-the-art cells is shown in Figure 1.

IV. Developed model to simulate:

(1) the consumption of methanol in a $MeOH/O_2$ cell, and

(2) the rate of crossover in a $MeOH/O_2$ cell. The model treated the influence of methanol kinetics on the cell near limiting current, and the influence of incomplete methanol conversion at the cathode at higher feed concentrations.

(F) Determined that the crossover of methanol can be modified using different electrode structures

Objective 3: (A) A fuel cell testing laboratory has been set up and several hundred cells have been tested. Both direct methanol and hydrogen fuel cells have been fabricated and tested. The facilities have been used to evaluate several combinations of anode alloy catalysts and carbon support materials in 25 cm^2 cells with Nafion membranes.

V. The effect of contaminant cations on Nafion conductivity has been measured for several (approx. 20) cations. Corrosion of stainless steel hardware in a fuel cell can contribute to loss of fuel cell performance by contaminating the Nafion membrane.

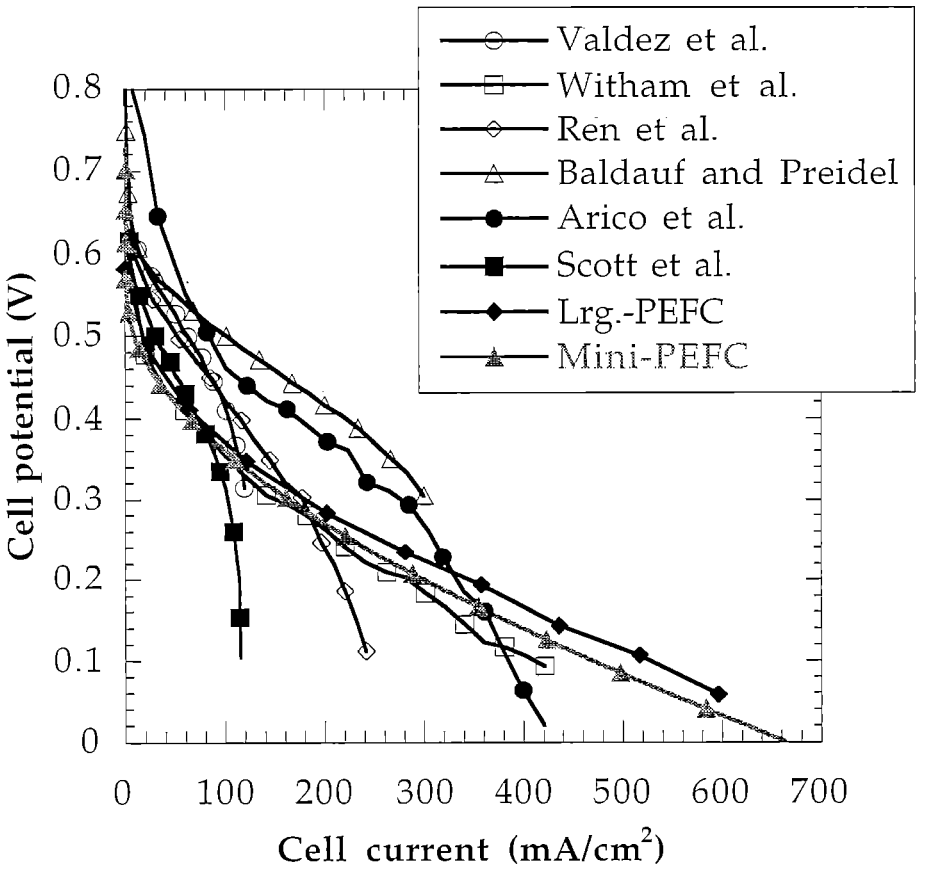

Figure 1. Comparison of Miniature and Large Polymer Electrolyte Cells with State-of-the-Art Cells. Catalyst Loading of the Miniature and Large Cells were 0.25 mg/cm^2 of Electrodeposited Pt-Ru on the Anode.

III. List of all Publications and Technical Reports

J. Meyers, R.D. Villwock, R.M. Darling, J.S. Newman, "Multicomponent Diffusion in a Gas-Diffusion Electrode with a Ribbed Flow Field Using the Quasipotential Transformation," in Advances in Mathematical Modeling and Simulation of Electrochemical Processes, Electrochemical Society PV 98-10 (1998).

B.S. Pivovar, Y. Wang, E.L. Cussler, "Pervaporation Membranes in Direct MethanolFuel Cells," J. Membr. Sci. **154**, 155 (1999).

S.C. Kelley, G.A. Deluga, and W.H. Smyrl, "A Miniature Methanol/Air Polymer Electrolyte Fuel Cell", Electrochemical and Solid-State Letters **3** (2000) 407-409.

C. Witham, S.R. Narayana, T. Valdez, and W. Chun, "Sputter Deposited Anodes for Direct Methanol Fuel Cells," Electrochem. Sol. State Lett. **3**, 497 (2000)

B. Libby, W.H. Smyrl, and E.L. Cussler, "Composite Membranes for Direct Methanol Fuel Cells," Electrochem. Sol. State Lett. **4**, A197 (2001).

S.C. Kelley, G.A. Deluga, and W.H. Smyrl, "Miniature Fuel Cells Fabricated on Silicon Substrates," AIChE J. (accepted for publication, October 2001).

S. Cheng and K.R. Mann, "The Electrocatalytic Oxidation of Methanol with Platinum Particles Preferentially Oriented on Highly Oriented Pyrolytic Graphite", (submitted to Electrochemica Acta, October 2001).

S.C. Kelley and W.H. Smyrl, "Electrodeposition of Pt-Ru Catalysts at Low-Loading," (manuscript in preparation).

IV. List of Inventions, Patents

None

V. List of all Participating Scientific Personel

Faculty who were involved in the MURI research:

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Professor David A. Shores	(University of Minnesota)
Professor Kent R. Mann	(University of Minnesota)
Adjunct Professor Boone B. Owens	(University of Minnesota)
Professor John S. Newman	(University of California-Berkeley)
Professor Du Shriver	(Northwestern University)

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Ph.D.:

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Jeremy Patrick Meyers, 1998 (University of California, Berkeley)
Bryan Scott Pivovar, 2000, (University of Minnesota, Chemical Engineering)
Shawn Christopher Kelley, 2000, (University of Minnesota, Chemical Engineering)
Hwang Chan Yoo, 2001, (University of Minnesota, Materials Science)
Brett Libby, 2001, (University of Minnesota, Chemical Engineering)

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